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Simulation of plasma fluxes to material surfaces with self-consistent edge turbulence and transport for tokamaks*

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The distribution of plasma fluxes to material surfaces is a key issue for fusion devices because it controls peak heat loads and determines hydrogenic and impurity particle sources via recycling and sputtering. The typical modeling approach for tokamaks has been to simulate the scrape-off layer (SOL) plasma with 2D transport codes that assume enhanced turbulence-induced transport across the magnetic field to fit experimental profiles. Plasma turbulence simulations for fixed profiles [e.g., Ref. 1] show that turbulent fluxes of the required magnitude arise from instabilities driven by the radial plasma gradients. However, because the profiles and turbulence are strongly coupled, being able to predict the plasma fluxes in future devices such as ITER requires coupling of simulations for turbulence and profile evolution. The approach reported here is coupling the BOUT 3D turbulence code [1] with the UEDGE 2D transport code [2]. Initial coupling of only the hydrogen density variable for fixed temperature profiles is presented in Ref. 3. Here the coupling is extended to the electron and ion temperatures and the parallel velocity. Neutrals are treated self-consistently via a full flux-limited fluid model. Because the characteristic time scales of the turbulence is short ($\sim 10^{-6}$ sec) and the profile evolution time scale can be long ($\sim 10^{-2} - 10^{-1}$ sec owing to recycling), an iterative scheme [4] is used that relaxes the turbulent fluxes passed from BOUT to UEDGE and the profiles from UEDGE to BOUT over many coupling steps. Each code is run on its own characteristic time scale, yielding a statistically averaged steady state. Since the turbulent fluxes are coupled directly to UEDGE with no assumption of small-amplitude diffusive transport, and the effect of strong, intermittent transport events are included. Results show that strong convective transport can arise in the far SOL for L-mode-like discharges, giving significant wall recycling. Comparisons are made between particle and energy fluxes to the main chamber walls and to the divertor plates for different conditions. The model is unique in its self-consistent treatment of turbulence and transport on both sides of the magnetic separatrix; thus, the model simulates the generation of the turbulence, its propagation to the wall, the resulting neutral influx, and profile modifications.

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